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OPTIMIZATION OF BRICK MIXTURE FORMULA BASED ON DRYING PROPERTIES

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Using mathematical modeling, the possibility of improving the drying properties of brick mixtures without using stony grog components is demonstrated. The proposed method can be recommended for the optimization of the drying process at brick and tile factories.

Drying of unburned bricks plays a significant role in stiff-mud brick production. This is due to the fact that even a slight variation in the drying properties of a brick mixture from the optimum values can significantly impair the overall production parameters: increase the amount of reject pieces, lower the product quality, decrease the efficiency, etc. It is known that there is no generally accepted method or a single criterion to estimate the optimum values of the drying properties of ceramic mixtures. In practice, the air shrinkage parameter is often used for this purpose. However, it does not offer a way for unambiguous prediction of the behavior of unburned bricks in drying.

This is explained by a series of factors. For example, the reference point in shrinkage measurements is not quantitatively determined, since the state of the mixture in molding which satisfies the normal working consistency is defined subjectively and organoleptically. Moreover, the drying rate has a strong effect on air shrinkage: the higher the drying rate, the lower the shrinkage. At the same time, the specified relationship is not the same for different clays.

It should be noted as well that, all other terms being equal, the shrinkage of samples is substantially affected by the value and the sign of stresses arising in unburned brick in molding.

Finally, even with the maximum possible standardization of the evaluation conditions, the drying properties cannot be put directly related to the air shrinkage, since the effect of the latter can be significantly leveled or intensified by the moist conduction of the mixture and other factors.

Similar considerations can be put forward with respect to the critical moisture, drying sensitivity coefficient, etc.

Therefore, when the Krasnodar ceramics factory needed to clarify the relationship between the formula of the industrial ceramic mixture and its optimum drying properties, we suggested using a set of parameters, namely: plasticity number, air shrinkage, drying sensitivity coefficient according to Chizhskii, and the rate of moisture removal when dried in the same conditions.

The said factory did not have classical grog materials at their disposal; however, three varieties of clay can be mined in the existent quarry: "black" clay (B), "rich" clay (R), and "mild" clay (M) which significantly differ in stiffness. These clay varieties were used to prepare experimental ceramic mixtures.

The investigations were carried out in accordance with the Shaeffe simplex lattice plan of the third order. The chosen factors were X_1 , X_2 , and X_3 , each corresponding to 100% "black," "rich," or "mild" clay, respectively (here and elsewhere mass content is indicated). All evaluations were carried out by the standard methods, with ageing of mixture for 10 days. The results averaged by three single measurements were processed according to the standard mathematical procedure to obtain an adequate regression equation, which makes it possible to calculate the response function value at any point of the factor space. Using the obtained regression equations, the values of the response functions were calculated in all nodal points (with a step of 10%), then the equal value points were selected and connected to obtain the isolines. The method used and the graphic depiction of the results make it possible to fully describe the effect of all components in any combination on a particular property (Figs. 1 – 4). The numerical values of the estimated properties are shown in Figs. 1 – 4 in the diagram apexes and in the isoline gaps.

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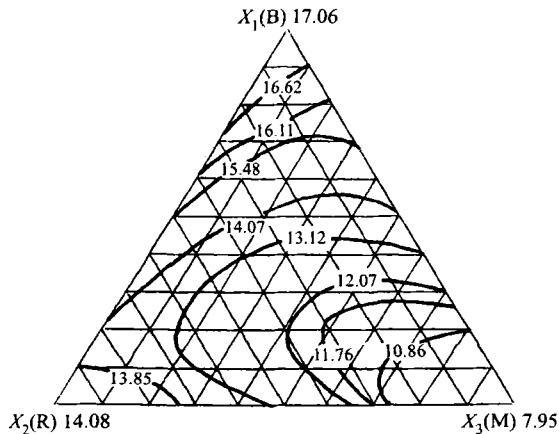


Fig. 1. Plasticity number.

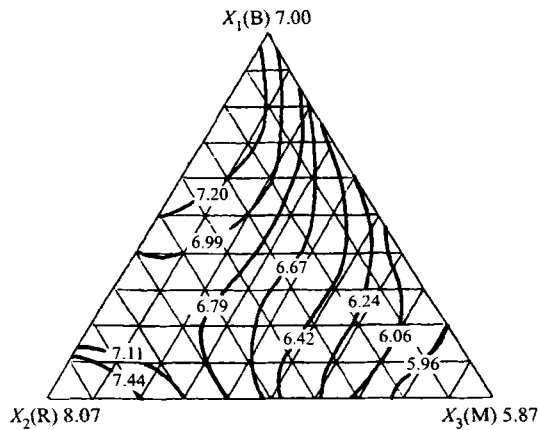


Fig. 2. Air shrinkage.

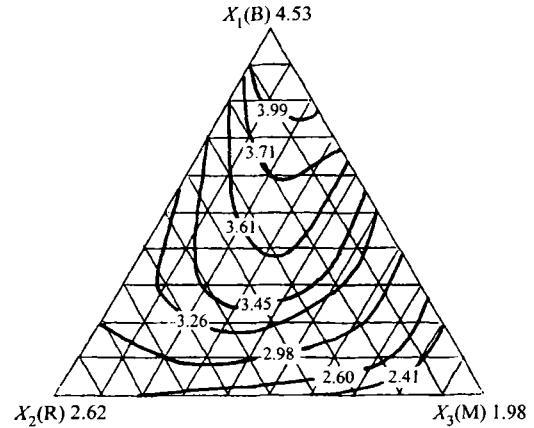


Fig. 3. Drying sensitivity coefficient according to Chizhskii.

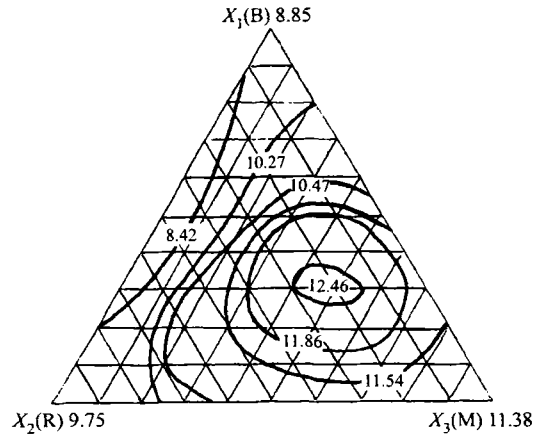


Fig. 4. Moisture loss (%) in 28 h drying.

Comparative analysis of the obtained data shows that any mixtures with a predominance of the softest "black" clay (X_1) exhibit the poorest drying properties for the considered system: the maximum values of shrinkage, drying sensitivity coefficient, and plasticity together with the relatively slow rate of moisture removal, which indicates low moisture conduction. Somewhat better parameters are seen in the region of compositions in which the "mild" clay content is below 20–30% and, therefore, the mixtures with the best drying properties ought to be in the right lower part of the diagram.

If one takes into consideration only shrinkage and the drying sensitivity coefficient, preference should be given to the pure "mild" clay, but the moisture loss rate of this mixture is not high. Therefore, in using pure "mild" clay, one cannot expect the maximum efficiency of the drying unit. At the same time, the mixture with the maximum moisture loss (12.46%, Fig. 4) is characterized by a relatively high drying sensitivity coefficient, which indicates that the product quality may be impaired, and thus makes it unacceptable.

To minimize the drying sensitivity coefficient and simultaneously preserve the relatively high moisture loss, it is expedient to shift the formula from the region of the maximum

moisture loss (Fig. 4) toward X_3 , i.e., toward the "mild" clay, provided its content does not exceed 80%. In this context, the best (compromising) combination of the drying properties is exhibited by compositions with the following content (%): 0–30 "black" clay, 0–40 "rich" clay, 60–80 "mild" clay.

Additional investigations established that due to substantial differences between the clay varieties, the "black" and "mild" clays have to be mixed to a very high homogeneity, which is hard to achieve under industrial conditions. Therefore, it is advisable to abandon the use of the "rich" clay.

Thus, the optimum composition should be a mixture of "rich" and "mild" clays with respective contents of 20–40 and 60–80%. This composition fully corresponds to the industrial mixture formula developed, adjusted, and used at the factory for a long period.

From our point of view, the above coincidence can be regarded as evidence of the reliability of the proposed method for estimating the optimum drying properties and formulas of brick mixtures, and therefore, the method can be suggested for optimization of the drying process at brick and tile factories.